Thin Membrane Fresnel Lens for Solar Thermal Propulsion

Vinson B. Huegele/EB52
205–544–3475
E-mail: vinson.huegele@msfc.nasa.gov

Solar concentrators made from deployable thin membranes offer a significant size and weight savings as a propulsion power source for spacecraft upper stages. A membrane cast into a fresnel lens can collect and focus the sun into a thermal cavity so that the energy absorbed there by a fluid creates a low thrust but a high initial specific impulse (Isp). MSFC is developing a demonstration in space of this solar thermal technology with the shooting star flight experiment.

A polyimide developed by Langley Research Center can be cast into an ultra-thin, strong membrane tolerant of space environments. Work has been ongoing since 1988 at MSFC on fabrication and testing of membrane reflectors with this polyimide[1]. The material has been produced into specimens that are 0.001-in thick and 8-ft wide. Although originally spin cast on flat plates, the material can be molded on a mandrel to produce a groove pattern. The polyimide membrane can be folded and stowed, then recover its shape when released and supported.

The shooting star flight experiment will use a deployable 6-ft-diameter f/1.25 fresnel lens to concentrate sunlight. A fresnel lens focuses light with a series of small concentric circular prismatic wedges instead of a curved surface, and can be molded into the polyimide membrane. A 12-in-diameter scale model was made to test and prove the concept, specifically the fabrication technique and the optical performance.

The optical prescription for the fresnel lens was designed and converted into a groove pattern compatible with the tooling controller on the Moore M-40 diamond turning machine at the MSFC Optics Branch. An aluminum blank was attached on to the machine and the grooves cut in the blank to make the mandrel. The mandrel was sent to United Applied Technology as part of a SBIR Phase 2 contract who cast the lens by pouring the dissolved polyimide onto the mandrel and spinning it in a temperature and humidity controlled environment. The cured lens was returned to MSFC where it was optically tested. The lens was fully illuminated by a collimated laser beam and the focused spot was observed and compared to the design value. The lens was also attached to a heliostat and the size and power distribution of the solar image was measured. Four lenses were produced and studied.

The lenses showed the casting and production process to be consistent. The measured optical performance was nominal, and the lens proved itself suitable as a concentrator. The focal length and solar image size were observed to be as predicted, but there were noticeable transmission losses through the lens due to the scattering from the very small groove pattern.

The success of this model allows the continuation of fresnel research and manufacturing to scale up to the full-size lens for the flight experiment. By making and testing a thin membrane fresnel lens from the polyimide, this investigation has expanded the data base and developed better expertise to understand the fabrication techniques and technology to make larger solar concentrators for upper stage propulsion. New designs and materials such as this are essential to further advance space deployable optics.

[1]Huegele, V.B.: “Thin Film Electrostatic Controlled Reflector.” *MSFC Research and Technology Report 1991*.

Sponsor: Office of Space Access and Technology

Industry Involvement: United Applied Technology

Biographical Sketch: Vinson Huegele is an optical physicist in the Optics Branch and is the optics lead for the shooting star flight experiment. Huegele has been with MSFC since 1980. He received his B.S. in physics from David Lipscomb University and his M.S. in engineering from the University of Tennessee Space Institute.